

Mechanical stability, muscle strength and proprioception in the functionally unstable ankle

Luke Ryan

Functional instability of the ankle is common following inversion sprain. Factors suggested as causes of this disability include mechanical instability of the talocrural joint, peroneal muscle weakness and motor incoordination due to impaired proprioception. This study documented physical examination characteristics of functionally unstable ankles relevant to these theories. Each ankle of 45 subjects with unilateral functional instability was examined. Mechanical stability was assessed by standard clinical instability tests. Evertor and invertor muscle strength was measured using the Cybex II dynamometer. The Uni-axial Balance Evaluator (UBE) was used to assess dynamic control of the ankle and was considered capable of detecting unilaterally impaired proprioception. Mechanical instability was frequently absent in the functionally unstable ankles tested. Evertor muscle strength was similar in the normal and functionally unstable ankles. UBE results were consistent with the theory of impaired proprioception contributing to functional instability, but the need for further research is emphasised.

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LG Ryan BAppSc(Phty), MAppSc(Phty) is a private practitioner in Adelaide.

Correspondence: Luke Ryan, Suite 5, 405 Torrens Road, Kilkenny, South Australia 5009.

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Inversion sprain of the ankle is one of the most common injuries of the musculoskeletal system, particularly amongst sportspersons. A residual disability frequently complicating this injury is functional instability (FI) of the ankle. This term refers to the ankle that repeatedly sprains or gives way (Freeman 1965). Most studies have found that FI complicates 10-20 per cent of all inversion injuries presenting for treatment (Moller-Larsen et al 1988, Niedermann et al 1981, Prins 1978). The incidence of this complication has been found to be independent of the severity of the injury and, in general terms, the treatment it receives (Evans et al 1984, Moller-Larsen et al 1988, Niedermann et al 1981).

Aetiology of FI

FI has been attributed to a number of aetiological processes. The most widely accepted is varus (adduction) and/or postero-anterior instability of the talus in the ankle mortise, ie that FI is a direct consequence of mechanical instability of the talocrural joint (Brostrom 1966, Prins 1978).

Tropp et al (1985) examined 159 functionally unstable ankles and found only 66 to be mechanically unstable, as indicated by a pathological anterior drawer sign. Several studies investigating the relationship between mechanical instability and FI have found no correlation between them (Evans et al 1984, Freeman 1965,

Termansen et al 1979).

Evertor muscle weakness is another factor proposed as a cause of FI. It has been suggested that evertor muscle weakness may occur due to inhibition caused by pain or oedema, inadequate rehabilitation and secondary muscle atrophy (Tropp 1986) or peroneal nerve injury (Nitz et al 1985). Most reports of evertor weakness have been based on manual testing. Tropp (1986) used a Cybex II dynamometer with a modified footplate to assess evertor strength of 15 patients with unilateral FI. A significant difference in peak eversion torque existed between the normal and the affected ankles at speed settings of 30 degrees/second and 120 degrees/second, representing a significant weakness of the evertors of the functionally unstable ankles.

Freeman et al (1965) hypothesised that when the ankle is sprained, articular partial de-afferentiation occurs, causing impaired proprioception. This affects stabilisation of the ankle, leaving it with a tendency to give way, ie functionally unstable. To test this theory, Freeman et al (1965) examined 46 patients an average of nine months after an ankle sprain. Based on visual assessment of the patients' stability when standing on the injured leg compared with standing on the uninjured leg, it was concluded that functional instability was primarily due

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to motor incoordination consequent upon articular de-afferentiation. This theory received support from the results of research by Glencross and Thornton (1981) and Garn and Newton (1988), who investigated the effect of ankle injury on joint position sense. Tropp (1986) claimed that stabilometry, used to measure postural sway, was an objective measure of the modified Romberg test used by Freeman et al (1965). Tropp (1986) used stabilometry to assess 15 sportspersons with unilateral FI and found them to demonstrate greater postural sway standing on either limb than a reference group of sportspersons without FI. There was no significant difference between stabilometric values recorded when standing on the affected and unaffected legs. It was concluded that subjects with FI had a defective mechanism for compensating disturbance of postural equilibrium. Friden et al (1989) used stabilometry to measure postural sway variables selectively in the frontal plane in 14 patients who had sustained acute ankle sprain. There was a significant difference when comparing injured and uninjured legs, representing poorer performance on the injured side.

By EMG monitoring of the reaction of functionally unstable ankles to unexpected inversion during weightbearing, Konradsen and Ravn (1990) revealed these ankles to have a prolonged peroneal muscle reaction time compared with normal ankles. They found that these subjects did not show a defect in central processing of afferent input and were of the view that the result substantiated the theory of proprioceptive deficit being responsible for FI.

DeCarlo and Talbot (1986) found that anaesthetisation of the anterior talofibular ligament, suggested to mimic articular de-afferentiation, had no significant effect on dynamic postural control. A device providing an objective measure of a subject's ability to balance on two multi-axial wobbleboards was used to quantify dynamic postural control. Whilst the results were not supportive of the

theory of Freeman et al (1965) it was suggested that a significant learning effect was responsible for improved performance following anaesthetisation. It should be emphasised that the theory of Freeman et al (1965) had its basis in the relationship considered to exist between articular mechanoreceptors and the muscles controlling the ankle. Doubt now exists about the significance of the role of articular receptors in proprioception with widespread experimental evidence supporting a dominant role for intramuscular receptors (Burke et al 1988, Clark et al 1989).

The aim of this study was to document some of the characteristics of the functionally unstable ankle in order to identify features requiring particular attention in the assessment and treatment of subjects presenting with this complaint. It was also hoped that the results would allow comment to be made on some of the existing theories of the cause of functional instability.

The particular characteristics investigated in this study were:

- (i) mechanical stability of the talocrural joint;
- (ii) strength of ankle evertors and invertors; and
- (iii) dynamic control of the ankle.

Method

Subjects were required to have a history of unilateral functional instability of the ankle. They must have sustained:

- (i) at least six episodes of giving way of the ankle into inversion, with or without pain, within the past 12 months; or
- (ii) a total of at least three inversion sprains, including two or more within the past 18 months, with at least one in the past six months.

A sprain was defined as an episode of giving way into inversion followed by more than two days of pain and restriction of function. The affected ankle must have recovered to its usual state since last giving way. All

sportspersons must have been fully engaged in their sporting activity for at least the two weeks prior to testing.

Subjects were excluded if they had sustained any other significant injury or suffered from any condition likely to cause a strength or mobility deficit in either lower limb or to cause disturbance of balance. Any subject reporting pain during UBE or Cybex II testing was excluded from the study.

Forty-nine subjects were recruited from netball clubs, Australian Rules football clubs and on referral from general practitioners, orthopaedic surgeons, physiotherapists and acquaintances. A questionnaire was used to establish suitability for inclusion in the study. Four subjects were excluded during testing – three experienced pain on strength testing and one complained of pain on UBE testing. Of the remaining 45 subjects, 33 were female. The age of subjects ranged from 16 to 35 years (mean = 23 years).

Measurement of dynamic control of the ankle

The Uni-Axial Balance Evaluator (UBE)

This device was designed to measure the time spent out of balance when subjects stood on one foot on a single axis wobbleboard. The device incorporated a wobbleboard, a supporting base with two microswitches and an electronic timing device. The wobbleboard sat on the non-slip surface of the supporting base (Figure 1). When the wobbleboard tilted 4 degrees or more in either direction, the edge of the board engaged one of two microswitches fixed to the supporting base. The board was permitted to tilt a total of 6 degrees in each direction before striking a mechanical stop.

The timing apparatus incorporated two independent identical electronic timers accurate to 0.1 seconds (Figure 2). Each microswitch was attached to one of the timers. This arrangement allowed independent measurement of the time spent out of balance by 4 degrees or more in each direction over a certain period.

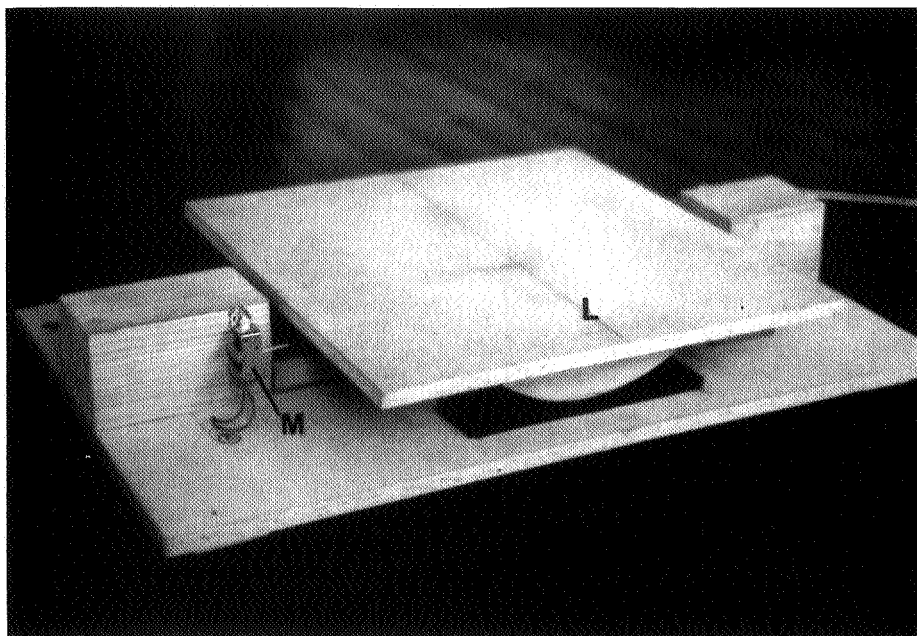


Figure 1.
UBE wobbleboard and supporting base. Note L (centre line on wobbleboard) and M (microswitch).

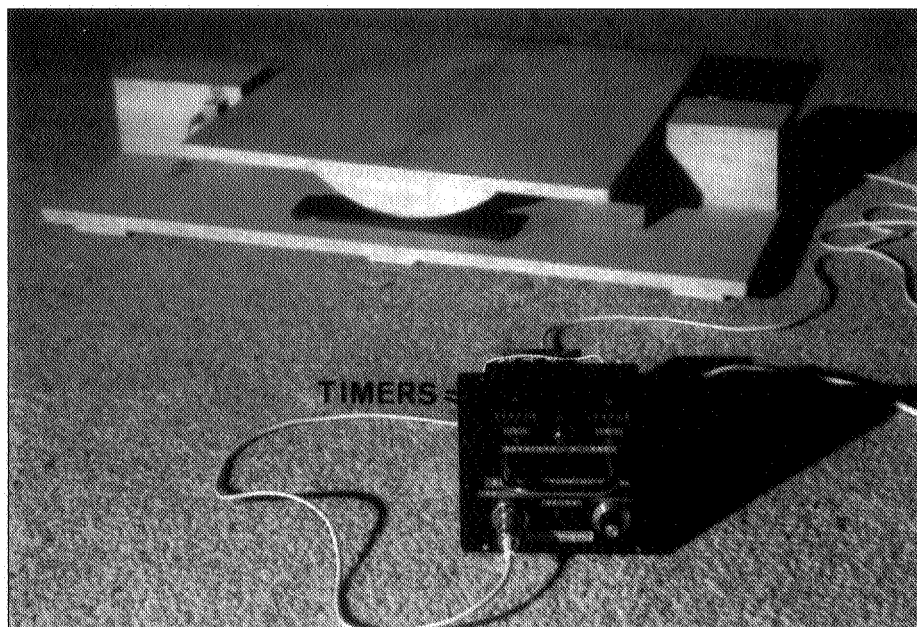


Figure 2.
UBE timing apparatus.

UBE test procedure

Each part of the test procedure was performed on the unaffected ankle before the affected ankle. The subject was allowed one minute standing on each leg on the UBE to become familiar with the rocking nature of the wobbleboard and the requirements of balancing on it. A trial run identical to the subsequent test procedure was then performed to further familiarise the subject with the demands of the test.

A block was placed under the wobbleboard to prevent it from tilting from the horizontal position. The subject's unaffected foot was positioned such that the central line passed under the centre of the second toe and the centre of the heel. The subject stood on the board weightbearing only on the unaffected leg and looked directly forward at a marker placed on the wall three metres in front of them. With the board blocked, the subject was asked to take note of this ankle position. The subject then placed the affected foot on the ground, keeping the unaffected foot in its position on the board and the block was removed. The subject then again stood on the board on the unaffected leg and was instructed to keep the board in its horizontal position whilst weightbearing on that leg. The subject again was asked to look at the marker. The subject was not permitted to touch the non-weightbearing foot on the floor or any part of the apparatus. After a five second period to allow the subject to become steady, the timing apparatus was activated. The subject's performance was recorded over a 30 second period. The same procedure was performed on the affected leg. The test was repeated a second time on each leg after a five minute rest.

Time out of balance score

The time out of balance score for each direction of tilt equalled the mean of the two test times recorded for that direction of tilt. The total time out of balance score was calculated by adding the mean scores for each direction of tilt. The tilt of the board corresponded to movement of the hindfoot in the

heel

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frontal plane. When the board engaged the lateral switch, the hindfoot was adducted. When engaging the medial switch, activating the medial timer, the hindfoot was abducted.

Measurement of muscle strength

The Cybex II dynamometer, incorporating the Cybex Speed Selector and Dual Channel System, was used to measure the strength of ankle invertors and evertors as described in the Cybex manual (Lumex Inc. 1983). The Upper Body Exercise Table (UBXT) allowed the subject to assume a suitable and stable test position. The unaffected ankle was tested before the affected ankle. A warmup and familiarisation routine required the subject to perform five submaximal and five maximal repetitions at a speed setting of 120 degrees/second and three submaximal repetitions and one maximal repetition at a setting of 30 degrees/second. The test procedure consisted of three maximal repetitions at 30 degrees/second. The evertor and invertor strength scores equalled the mean of the two highest peak torque values achieved from the three trials.

Instability tests

The two standard talocrural instability tests, anterior drawer and talar tilt, were performed manually on each ankle.

The talar tilt test was performed with the subject supine and the ankle in plantarflexion. The examiner's thumb was used to detect the gapping between the lateral malleolus and the talus. The movement was graded as:

- 1 = Very hypomobile
- 2 = Slightly to moderately hypomobile
- 3 = Normal
- 4 = Slightly to moderately hypermobile
- 5 = Very hypermobile

The anterior drawer test was performed with the subject supine with the knee flexed and supported at 60 degrees to help eliminate

gastrocnemius muscle tension. The amount of movement occurring at the talocrural joint was determined by palpating the movement that occurred between the talus and the malleoli, using the thumb and index finger on the lateral and medial aspects, respectively. This movement was graded as for the talar test.

It was considered that the functionally unstable ankle could be designated mechanically unstable if it was graded very hypermobile or if it received a grading of at least two grades greater than the unaffected ankle on either instability test.

Reliability studies

Prior to commencement of subject testing, inter-examiner and intra-examiner reliability studies were undertaken for instability test measurement procedures, using five subjects (10 ankles). The reliability of the UBE measurement was also determined using five subjects.

Results

Reliability studies

There was agreement in 19 of the 20 grades of movement found on instability tests performed by the examiner on five subjects on two separate occasions. There was agreement in 17 of the 20 grades of movement on instability tests recorded by the examiner and, independently, by another manipulative physiotherapist. In the three cases where the examiners failed to agree there was a difference of one grade.

The difference between UBE test scores of the unaffected and affected ankles of five subjects tested on one occasion were compared with the differences found on a second occasion. Paired *t*-test analysis revealed no significant difference between the values recorded at each examination ($t_{(9)} = 1.04$, $p = 0.325$). Pearson product moment correlation coefficient indicated a high degree of consistency ($r = 0.94$).

Instability tests

In 28 subjects, there was no difference between ankles in the grade of talar tilt. In 15 of the remaining 17 cases, the affected ankle had greater talar tilt than the unaffected ankle. Four subjects had two grades greater mobility in the affected ankle than the unaffected ankle. In all four cases, the affected ankle was very hypermobile and the unaffected ankle was normal. In three other subjects, the affected ankle was graded very hypermobile. In these three cases, the unaffected ankle was graded slightly to moderately hypermobile. The results of anterior drawer tests are shown in Table 1.

In 21 subjects, the affected ankle had at least one grade greater mobility than the unaffected ankle on either instability test. On the basis of this study's definition of mechanical instability, there were 11 mechanically unstable ankles amongst 45 functionally unstable ankles (24 per cent). Six of the 11 ankles were indicated to be mechanically unstable by both instability tests. A further four ankles were found to be mechanically unstable on anterior drawer test only. Only one ankle was categorised as mechanically unstable on the basis of talar tilt testing without this being indicated by the anterior drawer test.

Muscle strength tests

The mean strength score for the invertors of the affected ankles was 22.7 (± 8.4) Nm compared with a mean of 26.6 (± 8.5) Nm in the unaffected ankles. Using paired *t*-test analysis (two-tailed), this difference was found to be significant ($t_{(44)} = 4.99$, $p < 0.001$). Similar analysis revealed no significant difference in the mean strength score of evertors of the affected and unaffected ankles, with values of 18.8 (± 6.6) Nm and 19.2 (± 5.8) Nm respectively ($t_{(44)} = 0.7$, $p = 0.49$).

UBE tests

When standing on their affected leg, the 45 subjects spent an average of 5.4 (± 3.9) seconds out of balance. That is, during the 30 second test period, the wobbleboard deviated from its horizontal position by 4 degrees or

Table 1.

Results of anterior drawer tests (45 subjects). Asterisks indicate the cases in which the functionally unstable ankle had at least two grades greater anterior drawer than the unaffected ankle.

		Functionally unstable ankle			
		Slightly to moderately hypomobile	Normal	Slightly to moderately hypermobile	Very hypermobile
Unaffected ankle	Slightly to moderately hypomobile	2	2	1*	0
	Normal	3	16	5	4*
	Slightly to moderately hypermobile	1	0	5	4
	Very hypermobile	0	0	1	1

more for an average duration of 5.4 seconds. This compared with a mean score of 2.9 (± 2.4) seconds on the normal side. A statistical comparison of these means using paired *t*-test analysis (two-tailed) demonstrated a significant difference between the ankles in the mean total time spent out of balance ($t_{(44)} = 4.78, p < 0.001$). Of the total time out of balance, the affected ankle spent an average of 4.0 (± 3.7) seconds in a measurably adducted position and 1.4 (± 1.5) seconds in abduction. On the unaffected side, the results were 1.8 (± 1.7) seconds and 1.1 (± 1.4) seconds, respectively. There was no significant difference in the mean time spent with the ankle abducted ($t_{(44)} = 1.35, p = 0.19$), but a significant difference between the two ankles in the time spent tilted into adduction ($t_{(44)} = 4.01, p < 0.001$). This implied that the difference in the mean total time scores between the ankles was mostly due to the difference in the time that the lateral, or adduction, switch was engaged.

Factors influencing UBE test scores

Student *t*-test analysis demonstrated no significant difference between the UBE test scores in those functionally

unstable ankles designated mechanically unstable and those found to be mechanically stable ($t_{(43)} = 0.82, p = 0.42$).

Pearson product moment correlation coefficients revealed no significant relationship between the difference in UBE test scores in each of the subjects' ankles and the difference in the strength of invertors ($r = 0.05, p = 0.75$) or evertors ($r = 0.02, p = 0.91$).

Discussion

There are many theories about the cause of FI of the ankle. The current study provides comment on only three of these theories.

While the presence of FI without mechanical instability is frequently noted in the literature (Evans et al 1984, Freeman 1965, Termansen et al 1979), the percentage of subjects with mechanical instability of the functionally unstable ankle (24 per cent) in this study was surprisingly low. It is important to note that the majority of subjects included in this study were recruited from sporting clubs. Tropp et al (1985) demonstrated mechanical instability in 66 of 159 functionally unstable ankles (39 per

cent) in a group of subjects recruited in a way similar to that of the present study. These figures are not necessarily representative of the incidence of mechanical instability amongst patients seeking treatment for FI.

The evidence suggests that there were factors other than mechanical instability of the talocrural joint responsible for FI in 34 of the 45 subjects. Furthermore, the presence of mechanical instability in 11 subjects is not evidence of its aetiological significance in these cases. It has been suggested that repeated giving way may finally cause some mechanical instability rather than the mechanical instability initiating the FI (Freeman et al 1965). It is important in the clinical setting that when patients present for treatment of FI, the presence of mechanical instability is not considered to obviate the need to assess other possible contributing factors. It is reasonable to suggest that the appropriate management of these factors should apply whether or not the patient is treated surgically by a lateral stabilisation procedure.

The proposition that peroneal muscle weakness is responsible for FI is not supported by the results of this study. It is noted that the mean strength scores for the evertors of the unaffected ankle were higher than those of the affected ankle, although this difference was not significant. Due to the order of testing, any learning effect was biased in favour of the affected ankle and may have contributed to the closeness of the values.

The results of this study differ from those of Tropp (1986) who demonstrated significant pronator muscle weakness in 15 patients presenting to a hospital orthopaedic department because of unilateral FI of the ankle. Tropp (1986) used a Cybex II dynamometer but used a lighter footplate attachment, which was claimed to reduce gravitational torque and moment of inertia. In addition, unlike the current study, Tropp (1986) used the peak torque of the best of five trials for analysis. These factors are

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likely to explain the higher peak torque values of $20.2 (\pm 4.7)$ Nm and $23.0 (\pm 5.8)$ Nm recorded for evertors of affected and unaffected ankles, respectively. However they are unlikely to affect the relative strength scores of the affected and unaffected ankles. It is proposed that the conflicting results may be due to the aforementioned learning effect and to the difference in subject sample. It is likely that symptoms were more severe in subjects in Tropp's 1986 study as they were actively seeking help for the problem. Symptoms possibly caused reflex inhibition or elicited protective manoeuvres aimed at reducing stress on the affected ankle during daily activities or sport. This reduction in demand may have caused a degree of unilateral muscle atrophy and loss of strength.

Invertor strength in functionally unstable ankles is not known to have been measured previously. The marked invertor weakness in the functionally unstable ankles tested in the current study was an unexpected result and is not easily explained. It seems that repeated giving way into inversion is unlikely to be associated with direct injury of the invertor muscles. Therefore, two theories are offered. The weakness may be the result of selective inhibition, as described by Swearingen and Dehne (1964), due to the invertors' ability to initiate movement in the direction of initial injury. Alternatively, it is possible that invertor weakness is the result of interruption of the muscles' nerve supply. Indeed, Nitz et al (1985) found deep peroneal and tibial nerve injury to be quite common following inversion injury. Regardless of the explanation, invertor weakness seems unlikely to cause F1 of the ankle.

The current study used the UBE to assess dynamic control of the ankle in the frontal plane. It was considered that testing a subject's ability to maintain the ankle in a designated position while standing on an unstable platform such as a wobbleboard would place demands on the proprioceptive mechanisms responsible for initiating

appropriate activity in the muscles traversing the ankle.

Whether stabilometry, as used by Tropp et al (1985), or devices incorporating a wobbleboard such as the UBE, provide a valid measure of proprioception or kinesthesia around the ankle is open to question. Certainly the UBE could not be used to give a comparison of proprioceptive activity between two subjects, as performance will be influenced by many factors, in particular vestibular and visual input. An attempt was made to control the influence of visual and vestibular input by testing each ankle of subjects with unilateral FI rather than testing ankles in a group of normal subjects and a group of subjects with FI. However, the contribution of visual input, vestibular mechanisms and proprioception in the maintenance of postural equilibrium is not fixed. Impairment within one component is compensated for by an increased contribution from the other two components. This relationship may have contributed to the results of Tropp (1986) who found that stabilometric values did not significantly differ between affected and unaffected limbs in 15 subjects with unilateral FI of the ankle. It is noted that stabilometric values recorded for the affected and unaffected limbs were $314 \pm 87 \text{ mm}^2$ and $294 \pm 71 \text{ mm}^2$ respectively, with higher values indicating greater postural sway. The figures indicate a trend towards poorer performance on the affected leg. It is possible that standing on an unstable platform such as the wobbleboard of the UBE places more specific demands on proprioceptive mechanisms around the ankle than does standing on a force plate as in stabilometry. The validity of this suggestion is yet to be tested.

The significantly poorer UBE performance by subjects when weightbearing through their functionally unstable ankle suggests several possibilities. It indicates a unilaterally reduced capacity to detect ankle movement or position in the frontal plane or a less efficient muscle response to prevent deviation of the

affected ankle from the designated position in the frontal plane or a combination of these factors. The difference between ankles was the subjects' relatively poor ability to prevent tilt of the wobbleboard in the direction corresponding to adduction of the functionally unstable ankle, consistent with the direction of giving way. The difference was evidently not the result of mechanical instability of the talocrural joint or evertor weakness. It seems likely that prolonged peroneal muscle reaction time as described by Konradsen and Ravn (1990) was at least partly responsible for the UBE performance in functionally unstable ankles. The cause of the prolonged reaction time is yet to be determined.

While the results of the current study are in accordance with the theory of impaired proprioception due to articular de-afferentiation causing FI, several points require clarification. It is important to note that the presence of a proprioceptive deficit is not proof of its aetiological significance. Furthermore, given the uncertainty that exists about the role of articular receptors in proprioception (Burke et al 1988, Clark et al 1989) it is possible that injury occurs to intramuscular receptors within momentarily overstretched evertor muscles. A proprioceptive deficit may be the result of injury to neural structures other than receptors. It is not inconceivable that such a deficit is due to direct or indirect injury of the deep or superficial peroneal nerves. They are reportedly vulnerable to injury and entrapment with ankle inversion sprains (Nitz et al 1985) and they convey afferent signals from the muscles opposing the direction of injury as well as the ankle joint. While most patients with functional instability do not volunteer symptoms of gross nerve injury, there exists a need for further investigation into possible subtle neural transmission deficits in these patients.

Conclusion

The results of this research indicate that clinically demonstrable

mechanical instability of the talocrural joint is frequently absent in ankles with FI. While mechanical instability is likely to often contribute to FI, other aetiological factors must also exist.

Evertor weakness was not shown to be a dominant factor in FI of the ankle.

The results of UBE testing are consistent with the theory of a proprioceptive deficit causing FI. However, it is recognised that further research is required to confirm the presence, significance and cause of this deficit.

References

- Brostrom L (1966): Sprained ankles VI. Surgical treatment of "chronic" ligament ruptures. *Acta Chirurgica Scandinavica* 132: 551-565.
- Burke D, Gandevia SC and Macefield G (1988): Responses to passive movement of receptors in joint, skin and muscle of the human hand. *Journal of Physiology* 402: 347-361.
- Clarke FJ, Grigg P and Chapin JW (1989): The contribution of articular receptors to proprioception with the fingers in humans. *Journal of Neurophysiology* 61: 186-193.
- De Carlo MS and Talbot RW (1986): Evaluation of Ankle Joint Proprioception Following Injection of the Anterior Talofibular Ligament. *Journal of Orthopaedic and Sports Physical Therapy* 8: 70-76.
- Evans GA, Hardcastle P and Frenyo AD (1984): Acute rupture of the lateral ligament of the ankle: to suture or not to suture? *Journal of Bone and Joint Surgery* 66B: 209-212.
- Freeman MAR (1965): Instability of the foot after injuries to the lateral ligament of the ankle. *Journal of Bone and Joint Surgery* 47B: 669-677.
- Freeman MAR, Dean MRE and Hanham IWF (1965): The etiology and prevention of functional instability of the foot. *Journal of Bone and Joint Surgery* 47B: 678-685.
- Friden T, Zatterstrom R, Lindstrand A and Moritz U (1989): A stabilometric technique for evaluation of lower limb instabilities. *American Journal of Sports Medicine* 17:118-122.
- Garn S and Newton R (1988): Kinesthetic awareness in subjects with multiple ankle sprains. *Physical Therapy* 68: 1667-1671.
- Glencross D and Thornton E (1981): Position sense following joint injury. *Journal of Sports Medicine and Physical Fitness* 21: 23-27.
- Konradsen L and Ravn J (1990): Ankle instability caused by prolonged peroneal reaction time. *Acta Orthopaedica Scandinavica* 61: 388-390.
- Lumex Inc. (1983): Isolated joint testing and exercise: A handbook for using Cybex II and the UBXT. New York, Lumex Inc.
- Moller-Larsen F, Wethelund J, Jurik A, Carvalho A, and Lucht U (1988): Comparison of three different treatments for ruptured lateral ankle ligaments. *Acta Orthopaedica Scandinavica* 59: 564-566.
- Niedermann B, Andersen A, Andersen SB, Funder V, Jorgensen JP, Lindholmer E and Vuust P (1981): Rupture of the lateral ligaments of the ankle: operation or plaster cast? *Acta Orthopaedica Scandinavica* 52: 579-587.
- Nitz A, Dobner J and Kersey D (1985): Nerve injury and grades II and III ankle sprains. *American Journal of Sports Medicine* 13: 177-182.
- Prins JG (1978): Diagnosis and treatment of injury to the lateral ligaments of the ankle. *Acta Chirurgica Scandinavica* (Suppl.) 486: 1-152.
- Swearingen R and Dehne E (1964): A study of pathological muscle function following injury to a joint. *Journal of Bone and Joint Surgery* 46A: 1364.
- Termansen NB, Hansen H and Damholt V (1979): Radiological and muscular status following injury to the lateral ligaments of the ankle: follow-up of 144 patients treated conservatively. *Acta Orthopaedica Scandinavica* 50: 705-708.
- Tropp H (1986): Pronator muscle weakness in functional instability of the ankle joint. *International Journal of Sports Medicine* 7: 291-294.
- Tropp H, Odenrick P and Gillquist J (1985): Stabilometry recordings in functional and mechanical instability of the ankle joint. *International Journal of Sports Medicine* 6: 180-182.